Evaluation of the Venturi scrubber efficiency in the collection of particulate matter smaller than 2.5 µm emitted by biomass burning

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Introduction

Figure 1 : Sugarcane field
Taken from: https://www.embrapa.br/

Sugarcane is one of the most relevant biomass in Brazil due to its high energy generation potencial. In 2019, 639.0 million tons of sugarcane were processed (EPE, 2020). The bagasse from sugarcane processing is commonly burned for generation of electrical energy. However, this activity emits higher concentrations of gaseous and solid pollutants, especially particulate matter (PM) smaller than 2.5 µm, dangerous for environment and human health (SLAPNIG *et al*., 2018). The emission control in industrial processes is very important and can be done using equipments such as Venturi scrubbers, used for simultaneous cleaning of gaseous and particulate pollutants, with high efficiencies.

Figure 2: (a) Pilot biomass burner, (b) isokinetic sampler and (c) Venturi scrubber.

Objective

Evaluate a Venturi scrubber efficiency in the collection of PM smaller than 2.5 µm emitted by biomass burning.

Materials and Methods

- Automated pilot scale burner, consisting of rotary feeder, biomass burner, blowers, fans, a scrubber rectangular Venturi and a cyclone (Figure 2). Sugarcane bagasse was used for the tests;
- Rectangular Venturi scrubber of 117 mm in throat length, 2.4 cm in width and 3.5 cm in height;
- Liquid/gas flow rates of 0.6, 0.7, 0.8 and 1.1 L/m³. Water was used as washing liquid;
- Isokinetic samplers at the inlet and outlet of the scrubber, collecting three bands of d_P: $PM_{> 2.5\ \mu m}$, $PM_{1.0\text{-}2.5\ \mu m}$ and $PM_{< 1.0\ \mu m}$.

Results & Discussion

The results showed that the sugarcane bagasse burn emitted high concentrations of $PM_{2.5}$, but specially particles smaller than 1.0 µm responsible for the highest concentrations, as shown in Figure 3.

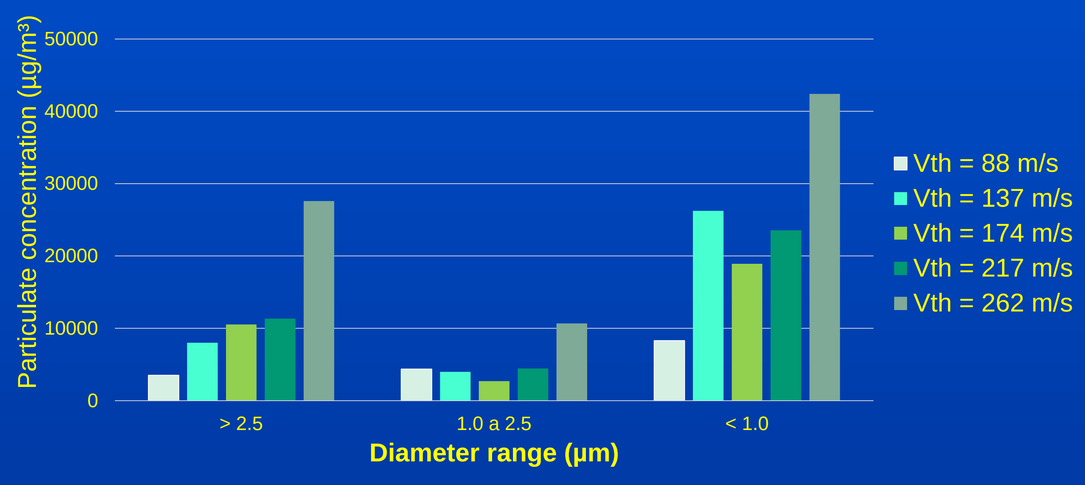

Figure 3: Average PM emission concentrations obtained from isokinetic sampler.

The difference between a non-sampled and a sampled filter could be seen with a scanning electron microscope (SEM). The Figure 4 shows an image of this situation, where it was visible the high concentration of particulates greater than 2.5 µm and smaller than 1.0 µm on the fibers of a sampled filter. It was interesting to see how the particulates were positioned, like small agglomerates forming even bigger structures. The particles diameter detected in the microscopy was ranging from 30 - 42 nm.

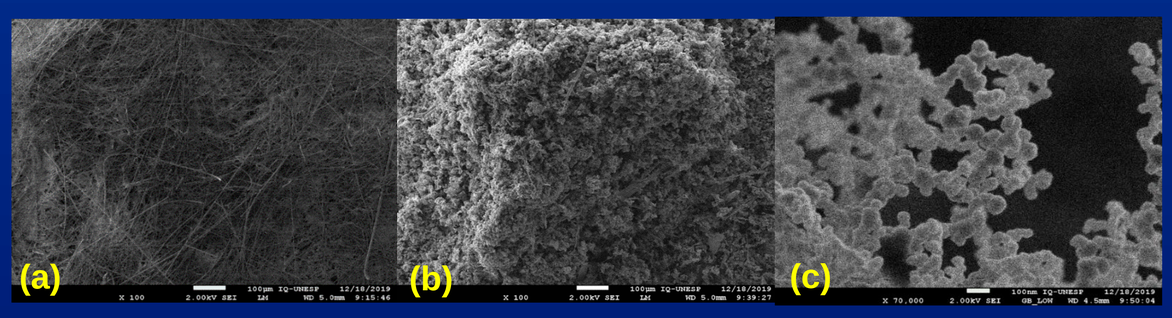

Figure 4: SEM image for (a) non-sampled filter, (b) sampled filter with d_P > 2.5 µm and magnification of x100; (c) and sampled filter with 1.0 µm and magnification of x70000 .

The Figure 5 shows a comparison between the PM concentration in the Venturi scrubber inlet and outlet, so it was possible to evaluate the efficiency of the equipment. The aspect of the sampled filters, before and after the cleansing of the combustion gases, was observed too.

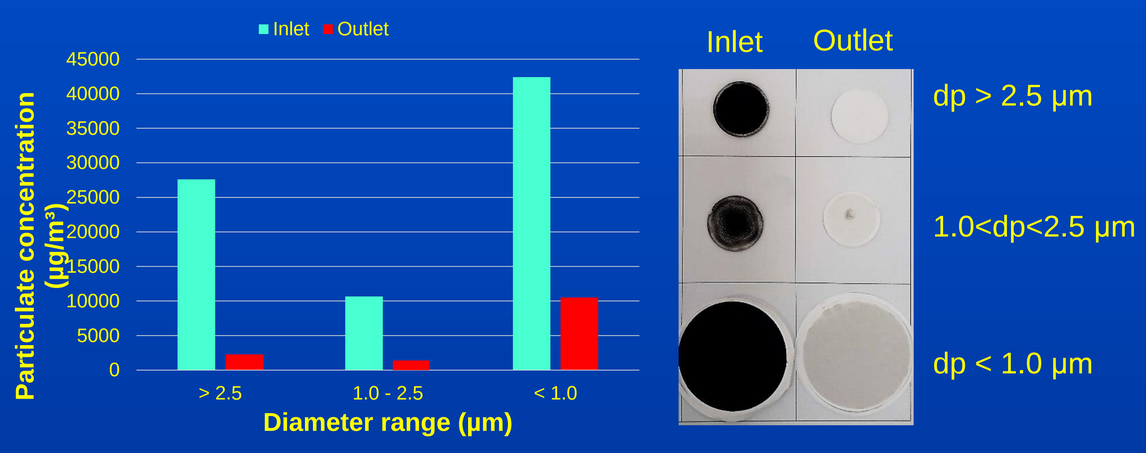

Figure 5: Comparison between the PM concentration in Venturi scrubber inlet and outlet and aspect of the sampled filters, with operational condition of V_{th} = 262 m/s.

A great performance of the Venturi scrubber in the collection of PM above 2.5 µm and between 2.5 and 1.0 µm was observed, with efficiencies ranging from 85.5% to 99.6%. The collection of PM smaller than 1.0 µm was satisfying, reaching efficiencies around 75.2%.

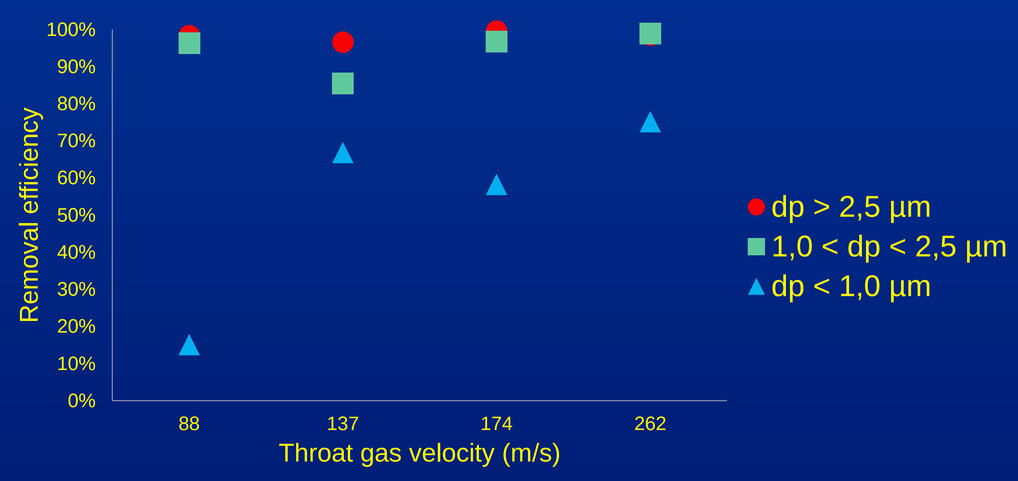

Figure 6: Removal efficiencies for each diameter range in isokinetic sampler.

Conclusions

The evaluation of the Venturi scrubber performance was very satisfying, especially in the removal efficiency of 75.2% of $PM_{1.0}$, the most dangerous for human health. This project showed that a Venturi scrubber can be interesting for industries that emit high PM concentrations, due to its size, maintenance costs and satisfying removal efficiencies for smaller particles.

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